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ROLE OF ORGANIC SPICES IN THE PRESERVATION OF SUB-SAHARAN AFRICAN TRADITIONAL FERMENTED BEVERAGES

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Abstract:-
A review of the antimicrobial action of a few plant based natural products in Africa is reported . Spices play preservative and flavoring roles in food , fermented beverages and nutrition security in sub Saharan Africa, thereby increasing the shelf life . The emphasis on organic spices is underscored by their being Generally Recognized as Safe, GRAS, thus enhancing the wholesomeness of such consumption. The compatibility of fermenting microorganisms' for various beverages is also noted. Volatile oils of black pepper, cloves, nutmeg, oregano and thyme have been shown to have antimicrobial activities against microorganisms.

Keywords: *Spices, Food Preservation, Shelf life, Fermented beverages*

1.0 INTRODUCTION

Spices and herbs are plant derived substances generally used as flavoring, coloring, and preservation agents in food or beverages. Some common spices include cumin, black pepper, coriander seeds, turmeric, ginger, fenugreek, cardamom, fennel seed, cinnamon, garlic, thyme, basil, oregano, cloves, basil etc. Organic spices are spices that are not irradiated or fumigated during their cultivation rather make use of natural fertilizers. They are free of pesticides, fresher with little or no preservatives and as such have better dose of nutrients, boosts immunity, fight diseases and delivers better taste. Many of these spices possess antimicrobial effects, and are derived from plant essential (volatile) oils which disrupt microbial cell membrane integrity, by negatively affecting the pH homeostasis and inorganic ions (Mokoshe et al., 2021). Consumers are seeking natural foods and natural preservatives for healthier lifestyles and natural ways of preventing ailments; therefore, spices are being sought for their medicinal value, as antioxidants, and as antimicrobials (Raghavan, 2006). Spices have also been used for a long period of time to preserve food and for treatment of diseases (Geremew et al., 2015). They have been shown to have antagonistic activity against microorganisms because of its natural antimicrobial substances and organic compounds. The main preservative effect of spices is exerted by their essential oils (EOs), which are known to be anti-microbiologically active (Ogbo and Igwillo, 2018).

Fermentation is one of the oldest methods for food preservation and globally it plays an important role in the processing of many indigenous food and beverages. Fermented products are appreciated, not only due to the preservation and safety of these products but also because of their sensorial attributes (Johansen et al., 2019). Moreover, several other beneficial effects of food fermentation have been reported including reduced loss of raw materials, reduced cooking time, prolonged shelf-life, enhanced bio-availability of micronutrients, and probiotic effects (Jespersen, 2003, 2005; Mufandaedza et al., 2006; Motlhanka et al., 2018). Most of these fermented products are produced in small-scale at small and medium-sized enterprises (SME) or at household level by spontaneous fermentation, sometimes including inoculation using back-slopping or repeated use of the same fermentation container (Holzapfel, 2002).

Fermentation being an ancient form of bio-preservation of food, improves the nutritional content and shelf life of foods. Fermented beverages are beverages which have undergone, a process of fermentation with Saccharomyces cerevisiae being the principal yeast species. They may be made from a variety of sugar-containing materials like cereals, fruits and vegetable juices, tea, and milk. Thus, the fermented beverages obtained from different sources are beer from barley/sorghum, kefir from kefir grains, wine from grapes, cider from apples, sake from rice, mead from honey, and other fermented beverages like probiotics (Kaur et al., 2019). In developing countries, traditional fermented food and beverage products form an important part of the food. Therefore, these food products are prepared from plant and animal materials in which microbes play an important role by altering the material physically and nutritionally. African raw plant and animal materials are predominated by many lactic acid bacteria (LAB) and yeasts. (Guesh and Anteneh, 2017). Traditional fermented beverages in sub-Saharan Africa includes: palmwine, ogogoro, pito, burukutu, maize beer, sorghum beer etc, while the fermented milk products are nono, mabisi, maishanu, wara, amasi, argo, omashikwa, mursik, kivuguto, lait caille etc. (Moonga et al., 2022). Traditional fermented foods are still diverse, but some are endangered, requiring actions to promote their preservation (Ojeda-Linares et al., 2021).

Fermented beverages are among the most iconic fermented foods worldwide; these are essential components of local diets in many cultures and are mainly prepared from plant substrates. They are associated with the presence of microorganisms known as probiotics, including bacteria (Lactobacillus, Bifidobacterium, Streptococcus, Leuconostoc, Pediococcus, Propionibacterium, Bacillus, and Enterococcus) and fungi (Saccharomyces, Aspergillus, and Candida) (Muhialdin et al., 2022). It has been reported that through fermentation, foods may be improved, preserved, and their organoleptic properties enhanced. Fermented products can have an important sociocultural role consumed during holidays, ceremonies, and rituals, and linked to fruiting seasons and the harvest of agricultural products (Tamang et al., 2012; Ojeda-Linares et al., 2021). Obafemi et al. (2022) reported that cereal fermented porridges or beverages with live and active microorganisms are much more common in Sub-Sahara Africa than in other places of the world. In some African countries in particular, cereals are used to produce indigenous fermented foods, nonalcoholic and alcoholic beverages. These beverages are popular because of the social, religious and therapeutic values associated with them (Aka et al., 2008; Djè et al., 2009). Some fermented beverages in Africa with their fermenting microorganisms is shown in Table 1.

Table 1: Some fermented beverages in Africa with their fermenting microorganisms

S/N	Fermented beverages	Country	Source Substrate	Shelf life	Microorganisms involved in Fermentation organisms	References
1	Mabisi	Zambia	Milk	Several days	*Lactobacillus plantarum, Lb. paracasei, Lb. rhamnosus, Pediococcus pentosaceus*	Moonga et al. (2022)
2	Nunu	Ghana Nigeria	Raw cow Milk	4 days	*Lactobacillus fermentum, Lb. plantarum, Lb. helveticus, Leuconostoc mesenteroides, Enterococcus faecium, E. italicus, Weissella confusa, Candida parapsilosis, C. rugosa, C. tropicalis, Galactomyces geotrichum, Pichia kudriavzevii, Saccharomyces cerevisiae*	Akabanda et al. (2013)
3	Omashikwa	Namibia	Milk	7-12 days	*Lactobacillus helveticus, Lb. rhamnosus, Lb. plantarum, Lb. kefiri, Lb. casei, Lb. rhamnosus, bL. paracasei* *Lactococcus lactis* *Leuconostoc pseudomesenteroides,* *Enterococcus faecium, E. durans*	Schutte (2013); Misihairabgwi and Cheikhyoussef (2017)
4	Masse	Mozambique	Milk	7 days	*Lactococcus lactis subsp. lactis* *Leuconostocs sp. (68%)* *Leuconostoc pseudomesenteroides, L. lactis, L. garlicum* *Enterococcus durans*	Schutte (2013)
5	Chekapmkaika	Uganda	Milk	29 days – a year	*Lactobacillus helveticus,* *Bacillus sp.* *B. cereus and B. thuringiensis*	Schutte (2013)
6	Amasi	South Africa, Zimbabwe	Milk	2-3 weeks @ low temperature	*Lactococcus lactis subsp. lactis (dominating), Lactococcus lactis subsp. cremoris, Lactobacillus, Enterococcus, and Leuconostoc spp. Several non-culturable strains*	Osvik et al. (2013)
7	Ergo (Sour milk)	Ethiopia	Milk	24-72hrs	LAB, yeasts and molds	Guesh and Anteneh (2017)
8	Arrera (defatted sour milk)	Ethiopia	Milk	24-48 hours	*Klebsiella pneumoniae, K. oxytoca, Enterobacter cloacae, Cronobacter sakazakii, E. coli and Salmonella sp.*	Bereda et al. (2014); Guesh and Anteneh (2017)
9	Teji	Ethiopia	Honey, water and leaves of gesho	NR	*S. cerevisiae, Kluyveromyces bulgaricus, K. veronae, Debaromyces phaffi, Lactobacillus, Streptococcus, Leuconostoc and Pediococcus species*	Guesh and Anteneh (2017); Hotessa and Robe (2020)

10	Zoom-koom	Burkina Faso	Millet/Sorghum	NR	*Lactobacillus, Leuconostoc, Lactococcus, Pediococcus and Weissella sp.*	Tapsoba et al. (2017)
11	Pito	Ghana, Nigeria	Malted sorghum, millet or maize	24-72 hrs	*Saccharomyces cerevisiae, Candida sp., Kluyveromyces sp. Rhodotorula glutinis, Pediococcus halophylus, Lactobacillus plantarum Leuconostoc, Lactococcus, Streptococcus, Enterococcus*	Sawadogo-Lingani et al. (2021)
12	Burukutu	Nigeria	Malted sorghum, millet or maize	3 days	*Acetobacter sp., Candida sp., Enterobacter sp., Lactobacillus sp., Saccharomyces cerevisiae, S. chavelieri, Leuconostoc mesenteroides, Rhodotorula glutinis, R. mucilaginosa*	Jimoh et al. (2012); Lyumugabe et al. (2012); Adewara and Ogunbanwo (2013)
13	Tchapolo	Côte d'Ivoire	Sorghum/ Maize/Millet	3 days	*Lactobacillus (L. fermentum, L. brevis, L. plantarum, L. hilgardii, L. coprophilus and L. cellobiosus), Leuconostoc, Pediococcus, Enterococcus, Candida sp., S. cerevisiae*	Aka et al. (2010)
14	Kaffir beer/bantu beer	South Africa	Sorghum	3 days	*Lactobacillus fermentum, Lb. plantarum, Lb. brevis, Lactococcus dextranicum, Saccharomyces cerevisiae, Candida krusei, Kloeckera apiculata*	Lyumugabe et al., 2012
15	Dolo	Burkina Faso	Sorghum	24-72 hrs	*Lactobacillus delbruecki, L. fermentum, Lactobacillus lactis, Pediococcus acidilactici, Saccharomyces cerevisiae, Lactococcus lactis, Weissella confusa, Enterococcus faecium, Pediococcus pentosaceus*	Glover et al. (2009); Solange, et al. (2014)
16	Bushera	Uganda	Sorghum millet	4-7 days	*Lactobacillus. plantarum, L. paracasei subsp. paracasei, L. fermentum, L. brevis and L. delbrueckii subsp. delbrueckii, Streptococcus thermophilus, Enterococcus*	Solange, et al. (2014); Mukisa et al. (2021)
17	Kunun-zaki	Nigeria	Millet sorghum or maize	24 hrs after production	*Lb. plantarum, Lb. pantheris, Lb. vaccinostercus, Corynebacterium sp., Aerobacter sp., Candida mycoderma, Saccharomyces cerevisiae, Rhodotorula sp., Cephalosporium sp., Fusarium sp., Aspergillus sp., Penicillium sp.*	Oguntoyinbo et al. (2011); Mokoshe et al. (2021)
18	Gowè	Benin	Sorghum/Maize/ Millet	2-3 days	*Lactobacillus fermentum, Weissella confuse, Kluyveromyces marxianus and Pichia anomala*	Michodjèhoun-Mestres et al. (2005); Vieira-Dalodé et al. (2008)
19	Tella	Ethiopia	Barley, wheat, maize, millet, sorghum, “teff” or other cereals.	10-12 days	*S. cerevisiae and Lactobacillus species*	Guesh and Anteneh (2017)

20	Borde	Ethiopia	Maize, sorghum, wheat, finger millet and tef and barley	24 hrs	*Weissella confusa, Lactobacillus brevis, Lactobacillus viridescens, Pediococcus pentosaceus and P. pentosaceus subsp intermedius*	Tafere (2015)
21	Keribo	Ethiopia	Barley and Sugar	1 or 2 days	LAB	Tafere (2015), Hotessa and Robe (2020)
22	Mahewu (amahewu)	South Africa	Maize	< 4 days	*Lb. fermentum, Lb. brevis, Lb. salivarius, S. cerevisiae, Candida haemuloni, Candida sorbophila, Debaryomyces hansenii*	Sekwati-Monang (2011); Solange, et al. (2014)
23	Kwete	Uganda	Maize and malted millet flour	24 h 24-48hrs	*Lactobacillus sp., Lactococcus sp., yeasts*	Namugumya and Muyanja (2009)
24	Otika / Oti-oka	Nigeria	pearl millet / sorghum	NR	*B. cereus, B. subtilis, C. krusei, C. tropicalis, Enterobacter clocae, L. brevis, L. fermentum, L. plantarum, Leuconostoc mesenteroides, S. cerevisae*	Oriola et al. (2017); Ogunbanwo and Ogunsanya, 2012
25	Safari (Sorghum) beer	Cameroon	Sorghum	3 days	*Salmonella sp., Listeria monocytogenes, Penicillium expansum, P. verrucosum, Aspergillus ochraceus, A. flavus*	Desobgo et al. (2013); Konfo et al. (2015)
26	Ikigage (Sorghum) beer	Rwanda	Sorghum	3 days	*Saccharomyces cerevisiae, Issatchenkia orientalis, Lactobacillus fermentum, Lactobacillus buchneri*	Kayode et al. (2005); Kayode et al. (2007); Lyumugabe et al. (2013)
27	Kounou	Cameroon	Sorghum	NR	LAB Yeasts, coliform	Bayoi et al. (2021)

NR – Not Recorded LAB – Lactic acid bacteria Lb. - Lactobacillus L. – Lactococcus S. - Saccharomyce

2.0 Importance of Microorganisms in Fermented Beverage

Microorganisms play important roles in fermented beverages and it includes:

- Improvement of organoleptic properties - Microbial fermentation results in an improvement on the organoleptic properties (texture, aroma, and flavor) of fermented beverages (Braide et al., 2018). LAB is responsible for the production of organic acids and a high diversity of antimicrobial agents, which ensures the upkeep of quality and the palatability of fermented foods (Hotessa and Robe, 2020).

- Use as probiotics - Probiotics are microbial food supplements with beneficial effects on consumers. They compete with pathogens for adhesion sites, to antagonize pathogens, or to modulate the host's immune response (Gqaleni and Alfred, 2007; Mulaw et al., 2020). Fermented beverages are believed by many communities to have medicinal value, hence increase in its consumption. Most probiotic products contain LAB and molds that have been found to produce antibiotics and bacteriocins (Mutanda et al., 2016; Guesh et al., 2019).

- Provision of nutritional quality – During fermentation, anti-nutrient factors decline as proteins and the content of the water-soluble vitamins increase (Braide et al., 2018). There is also increase in digestibility and bioavailability of micronutrients such as zinc, calcium, phosphorous iron, and amino acids (Hotessa and Robe. 2020).

- Bio-preservative properties –Many bacteria associated with fermented foods produce antimicrobial bioactive molecules, such as hydrogen peroxide, organic acids, and bacteriocins, which make them effective. Acid content plays an important role in alcoholic beverages for the preservation of beverages. The acid produced inhibits the growth of pathogenic microbes which can cause disease, thereby, prolonging the shelf life of fermented beverages (Hotessa and Robe. 2020).

3.0 Safety issues with traditional fermented beverages

Traditional fermented beverages are mostly home-made, unregulated beverages as they are produced outside government regulation without any rules or regard to standard food safety guidelines (Okaru et al., 2019). They are mostly packaged in used plastics that may not be sanitary. The lack of extensive regulations for most traditional beverages in developing countries can affect public health because these products often contain compounds that are fermented by microorganisms, which may lead to food infection, intoxication, renal failure and other chronic illnesses. Sometimes a product may be regulated at the production stage but not during sales where the products can be displayed and sold under direct sunlight or inappropriate temperatures (Nwaiwu et al., 2020). It was pointed out by Capozzi et al. (2017) that spontaneous food fermentations pose potential risks to human health and that the spontaneous fermentation by autochthonous microorganisms in traditional beverages requires a careful understanding and controlled processes to avoid food poisoning. Disease outbreaks from the consumption of contaminated products in most sub-Saharan Africa are not well monitored which may be due to the reluctance by public health authorities to rapidly confirm and respond to outbreaks (Omoleke et al., 2018). Apart from the microflora involved in spontaneous fermentation of beverages during processing, poor hygiene organisms can occur at any point during the production or storage of finished products and public sales which may lead to microbial contamination and ultimately food-borne diseases.

More bacteria than fungi species were reported for nunu and the most prevalent fungal genus was Candida spp. Escherichia sp. was found to be predominant over the natural Lactobacillus milk organism which suggests serious hygiene issues (Nwaiwu et al., 2020). Kunu has be shown to be susceptible to post-process contamination as some studies carried out on the product show that Escherichia and Bacillus species was highest in this product when compared to others reviewed (Mbachu, et al., 2014; Onyemekara et al., 2018; Blessed et al., 2017; Umaru et al., 2014).

A comparison between freshly processed and street-hawked kunu (Amusa & Odunbaku, 2009) showed that the fresh samples were free of coliforms whereas products found on the street were not. The main fungal isolates Aspergillus, Penicillium, and Fusarium suggest the possibility of mycotoxin presence (Nwaiwu et al., 2020). Pito beer has a very short shelf life and is normally consumed within a day after production. The bacteria and fungi associated with the drink in different Nigerian cities have been reported by Kolawole et al. (2007); Gazuwa et al. (2016); Sanni and Lonner (1993) and Orji et al. (2003). The microorganisms harboured by burukutu have been characterized (Chilaka et al., 2018; Anaukwu et al., 2015; Lynn et al., 2014; Stanley et al., 2014). Unlike pito, which have a low prevalence of hygiene indicator organisms, burukutu showed a high prevalence of Escherichia and Staphylococcus among the studies reviewed) possibly because of its physicochemical properties that allow bacteria to thrive. Aspergillus prevalence may be a source of aflatoxins and it has been demonstrated to be present in the drink (Olaniyi and Akinyele, 2019). Bacillus, Escherichia and Staphylococcus typically found in all traditional fermented beverages are well known for foodborne outbreaks which can occur due to post-process contamination and their presence suggests poor hygienic conditions during the preparation and storage of beverages.

4.0 The use of organic spices to extend the shelf life of traditional fermented beverages

Owing to the nature of the process involved in the production of traditional fermented beverages, it is highly susceptible to contamination by food spoilage microorganisms, leading to inconsistent quality and short shelf-life (Mokoshe et al., 2021). Locally prepared beverages may serve as vehicles for zoonotic and food-borne diseases such as staphylococcosis, salmonellosis, brucellosis, tuberculosis, listeriosis, and shigellosis because of their unhygienic conditions of processing. Volatile oils of black pepper, cloves, granium, nutmeg, oregano and thyme have been shown to have antimicrobial activities against Enterococcus faecalis, Escherichia coli, Salmonella pullorum, Staphylococcus aureus and Yersinia enterocolitica (Dorman and Deans, 2000). Cinnamon volatile oils and their active compounds (cinamaldehyde and eugenol) have also shown antimicrobial activities against E. coli, Pseudomonas aeruginosa, E. faecalis, S. aureus, Staphylococcus epidermidis, Klebsiella pneumoniae, Salmonella sp. and Vibrio parahaemolyticus (Chang et al., 2001). In addition, In vitro antimicrobial effects have also been attributed to many other volatile oils, including garlic, black cumin seeds, lemon grass, onions and laurel (Kraig, 2013).

Mokoshe et al. (2021) investigated various food spices, including cinnamon, garlic, and nutmeg, as potential preservatives that could be used to extend kunun-zaki shelf-life. The result of their study showed that organic spices (particularly garlic) increased the nutritional content of the kunun-zaki varieties and could potentially be used as natural preservatives for enhancing the kunun-zaki shelf-life. spices (ginger and garlic) have antimicrobial effect and are capable of destroying pathogenic bacteria (Ayo et al., 2003). Investigations have shown that the shelf-life of pito can be extended through pasteurization and/or the addition of Moringa oleifera leaf extract for up to 28 days. Though, the pito samples that contained the moringa extract were less favored by consumers (Ayirezang et al., 2016).

According to Dahouenon-Ahoussi et al. (2012), the use of essential oil of Citronella (Cymbopogon citratus) at 1 ml/L was effective in stabilizing African sorghum beer against the spoilage effects of continued fermentation. Rodrigue-Christian et al. (2014) also evaluated the influence of Hemizygia bracteosa (Benth) leaf powder on the quality of chakpalo produced in Benin and reported that the use of the powdered leaves during mashing had an effect on the physico-chemical parameters, providing a slightly sweet drink, less acidic, with low alcohol content. Edward and Ohaegbu (2012) studied the effect of ginger and garlic on the microbial load and shelf life of Kunun-zaki and found garlic (2g in 200mls or 0.01%w/v) to be most effective in reducing microbial populations. This was able to extend the shelf life of ginger-kunun-zaki for 6days as against 24hr control. Likewise, Echefu (2020) investigated the effect of bitter leaf extract on microbial load and shelf- life of locally brewed sorghum beer (Burukutu) and found that the aqueous extract of Vernonia amygdalina could extend the shelf-life of Burukuta.

Table 2: Some organic spices used to extend the shelf life of traditional fermented beverages

S/N	Fermented Beverage	Spices used to extend shelf life	Self-life	Enhanced Shelf-life	Concentration used	Storage Temperature	Reference
1	Kunun-zaki	Garlic	24 hrs	4 days	0.01(w/v) 2g in 200 ml	Ambient room temperature	Edward and Ohaegbu (2012)
		Garlic		96 hrs	0.01(w/v) 5g in 500 ml		Mokoshe et al. (2021)
		West African black pepper (Piper guineense)		4 weeks	0.01 – 0.015 (w/v) 10.0-15.0g extract/L	Ambient room temperature (28±2ºc	Orishagbemi et al. (2020)
2	Borde	Moringa Oleifera Thymus schimperi	24 hrs	10 days	10 g/100 ml	Ambient room temperature	Nemo and Bacha (2021)
3	Pito	Moringa Oleifera	24-72 hrs	28 days	25% Moringa extract +	Ambient room temperature	Ayirezang et al.(2016)

					Pasteurization (75-80 °C)		
		Essential oil of Citronella			1ml/L of Cymbopogon citratus		Rodrigue - Christian et al. 2014
4	Mahewu	Aloe vera (Aloe barbadensis) powder	<4 days	15 days	10 g of AVP	36 ± 2 °C.	Mashau (2020)
5	Burukutu	Ginger	3 days	6 days	0.1(v/v) 100 ml in 1L	Ambient room temperature	Ogbo and Igwillo (2018)
		Ethanol extracts of Garlic + Ginger		14 days	0.2 (w/v) 40g in 200ml		Mbajiuka et al. (2014)

5.0 Conclusion

Fermentation is one of the oldest methods for food preservation and globally it plays an important role in the processing of many indigenous food and beverages. Traditional fermented beverages are indigenous to sub-Saharan Africa countries. Essential oils of spices are the main preservative effect of spices and are known to be anti-microbiologically active. These have been demonstrated to extend the shelf life of traditional fermented beverages by several researchers.

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